

Preparation of electromagnetic shielding wood-metal composite by electroless nickel plating

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Abstract: Electrical and electromagnetic shielding wood-metal composite was prepared by using electroless nickel plating. The effects of solution amount, plating time and plating temperature on surface resistivity and electromagnetic shielding effectiveness were investigated. And P content, microstructure and surface feature of layers obtained at different temperatures were analyzed by energy dispersion spectrometer (EDS), X-ray diffraction (XRD) and scanning electron microscopy (SEM). The results showed that layers with higher electro-conductivity and electromagnetic shielding effectiveness were obtained under the optimum conditions that plating solution was 500 mL, plating time was 30 min and plating temperature was 62°C. The results showed by EDS analysis that P content increased gradually in a small extent with plating temperature increased. It was showed by XRD and SEM analysis that layers plated at different temperatures were all microcrystalline structure and uniform and successive, which had noticeable metal luster. Those indicated that plating temperature had little influence on microstructure and surface feature under pH value invariable.

Key words: Wood veneer; Electroless plating; Composite; Surface resistivity; Electromagnetic shielding

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Introduction

With the development of economic and society, more and more electronic equipment have been widely used. The amount of electromagnetic radiation has much increased. However, electromagnetic radiation has threat to human health and society (Liu *et al.* 2002). So more and more electromagnetic shielding materials were used to prevent or reduce electromagnetic radiation (Zhang *et al.* 1997; Huang *et al.* 1999; Zhao *et al.* 2001). There are three main kinds of electromagnetic shielding materials which conclude metal foils, alloy materials and electrical composites. In generally, 30–35 dB of shielding effectiveness is regard as effective, higher is certainly wanted.

As well known, wood is a kind of natural polymeric material with very poor electro-conductivity and electromagnetic shielding properties. Some types of wooden electromagnetic shielding materials have been reported and all have a weight disadvantage. The weight of the composite increases greatly when a metal plate or metal powder was used (Nagasawa *et al.* 1999). In this paper, electroless plating process was applied to wood veneer to coat the surface with Ni-P alloy to obtain lightweight wooden electromagnetic shielding material. This wood veneer plated with Ni-P alloy can replace metal plate bonded with a laminated wood panel to produce electromagnetic shielding composite materials. Since 1989, Japanese researchers has made wood metallized on the surface by electroless nickel plating (Nagasawa and Kumagai 1989; Nagasawa *et al.* 1990, 1991, 1992, 1994). The plated wood veneer was electrical and had the function of electromagnetic

shielding. But the plating solution used in their study was more expensive, meanwhile, the surface composition and structure was not analyzed. In this study, the effects of test conditions such as solution amount, plating time and plating temperature on surface resistivity and electromagnetic shielding effectiveness of plated veneer were discussed. Furthermore, the relationship of plating temperature with P content, microstructure and surface feature was investigated.

Materials and methods

Wood veneer in this study is also from *Larix Gmelini* and the thickness is 0.6 mm. The veneers were dried by air and made samples. The schematic of the sample, the operating procedures and analysis methods can be seen in the other paper (WANG Li-juan *et al.* 2005). There is only a little difference in figure of measuring the electromagnetic shielding effectiveness. Figure 1 shows the system of the apparatus for measuring the electromagnetic shielding effectiveness.



Fig. 1 System of apparatus for measuring shielding effectiveness

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Results and discussion

Effects of plating solution amount on surface resistivity and electromagnetic shielding effectiveness

With plating solution amount used in the procedure increased, the surface resistivity and electromagnetic shielding effectiveness of the plated veneer were decreased and improved (shown in Table 1 and Figure. 2). It is known that more solution can provide more Ni^{2+} which can transform to Ni after oxidation-reduction reaction and deposit on wood surface. Enough Ni deposition can form successive layer which endows wood with electro-conductivity and electromagnetic shielding effectiveness. When 100 mL plating solution was used, layer obtained was not successive, which had poor electro-conductivity and electromagnetic shielding properties. But successive and thin layer was deposited when plating solution was up to 200 mL. It was observed that the amount of plating solution was increased from 300 mL to 400 mL and from 400 mL to 500 mL, the surface resistivity of the plated veneer decreased and the relevant electromagnetic shielding effectiveness improved gradually. But the increasing step became smaller and smaller. Those indicate that 500 mL solution is optimum to obtain better layer.

Table 1. Effect of solution amount on surface resistivity of plated veneer

Solution amount/mL	Surface resistivity/ Ω/\square		
	Across fiber	Parallel fiber	Average
100	3.6019	2.1391	2.8705
200	1.1977	0.7655	0.9816
300	0.7678	0.5018	0.6348
400	0.5640	0.3976	0.4808
500	0.3692	0.2766	0.3229

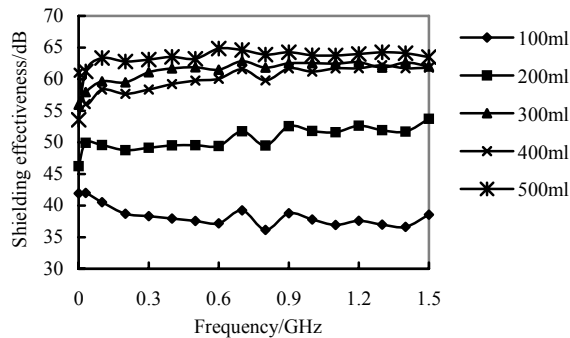


Fig. 2 Effect of solution amount on electromagnetic shielding effectiveness of plated veneer

Effects of plating time on surface resistivity and electromagnetic shielding effectiveness

In the process of electroless nickel plating, Ni deposition always occurs on the raised part on wood surface. And the reaction is very slowly in the beginning of the plating. So enough time is necessary for Ni unit cell to go up and form successive and thicker layer. As shown in Table 2 and Figure 3, the layer obtained was not ideal when plating time was 20 min. when wood veneer was plated for about 30 min, the electro-conductivity and electromagnetic shielding effectiveness were much higher. At that moment, majority Ni^{2+} was consumed, which led to no more Ni deposition. Therefore the electro-conductivity and electro-

magnetic shielding effectiveness also did not change significantly if plating time was prolonged on the base of 30 min.

Table 2. Effect of plating time on surface resistivity of plated veneer

Plating time/min	Surface resistivity/ Ω/\square		
	Across fiber	Parallel fiber	Average
20	0.8617	0.5396	0.7007
30	0.3736	0.3139	0.3437
40	0.3635	0.2722	0.3178
50	0.5579	0.4126	0.4852
60	0.3521	0.2642	0.3081

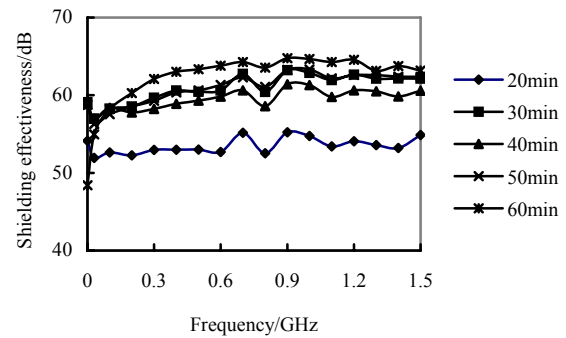


Fig.3 Effect of plating time on electromagnetic shielding effectiveness of plated veneer

Effects of plating temperature on surface resistivity and electromagnetic shielding effectiveness

Temperature is one of the important factors for electroless nickel plating under invariable pH value. According to Equation 1, higher temperature can increase electromotive force (E) which has effect on reaction rate. Higher electromotive force can promote nickel plating. Thus, electroless nickel plating can not begin at low temperature, but too high plating temperature will decrease the stability of the plating solution and accelerate the self-decomposition. Therefore, moderated temperature can obtain layer with good functions but have little influence on solution.

$$E = E^0 + \frac{RT}{ZF} \ln \frac{(a_{\text{H}_2\text{PO}_2^-})^2 (a_{\text{Ni}^{2+}})}{(a_{\text{HPO}_2^{2-}})(a_{\text{H}^+})^2} \quad (1)$$

As shown in Table 3 and Figure 4, the electro-conductivity and electromagnetic shielding effectiveness of veneer plated at 62°C are close to those at 64°C, 68°C or 72°C. And the deposition reaction can be controlled easily.

Effects of plating temperature on P content, microstructure and surface feature

In order to investigate the effects of plating temperature on P content, microstructure and surface feature of the layer, those of the layers plated at different temperatures were analyzed. It is known that the layer composition is Ni-P alloy for $\text{NaH}_2\text{PO}_2 \cdot \text{H}_2\text{O}$ was used as the reduction agent in plating solution. The results of P content of layers obtained at different temperatures were shown in Figure 5. It indicates that P content in the layer will

increase gradually with plating temperature increased at the temperature from 58 °C to 72 °C under an invariable pH value. As shown in Fig. 6, an acute XRD pattern from Ni(111) and two faint XRD peaks from Ni(220) and Ni(311) appear for each layer at different plating temperatures at the angles of $2\theta=44.5^\circ$, 76.4° and 92.9° , which indicate that each layer has a microcrystalline structure with small grains. So plating temperature has little effect on the microstructure of the alloy layer under an invariable pH value.

Table 3. Effect of plating temperature on surface resistivity of plated veneer

Plating temperature/°C	Surface resistivity/ Ω/\square		
	Across fiber	Parallel fiber	Average
58	0.8256	0.5772	0.7014
62	0.3867	0.2890	0.3378
64	0.4305	0.2837	0.3571
68	0.3374	0.2524	0.2949
72	0.3379	0.2391	0.2885

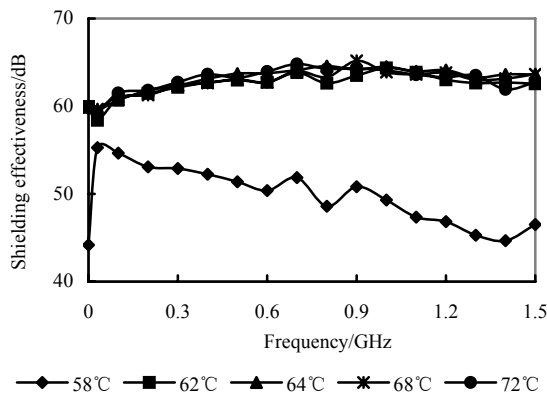


Fig.4 Effect of plating time on electromagnetic shielding effectiveness of plated veneer

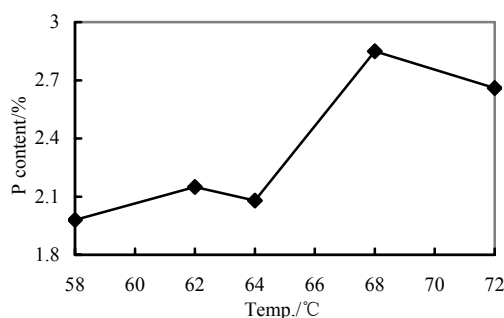


Fig.5 P content of veneers plated under different temperatures

It was observed from the micrograph of each layer plated at different temperatures in Figure 7 that the surface of wood veneer was covered entirely with very uniform and successive layer not only on the raised part but on inner layer of cell wall, which make wood surface more like metal and give wood more beautiful outlook. The layer can not caulk apertures in the surface so that it is also found that the surface of the plated veneer has the same porous structure with that of un-plated one. Each layer has

almost the same metal luster and appearance. Therefore it can be said that plating temperature at the range from 58 °C to 72 °C has little influence on the surface feature under an invariable pH value. In fact, microstructure and surface feature are closely related to P content. When P content is lower than 7%, the layer is generally microcrystalline, which gives the layer more metal luster.

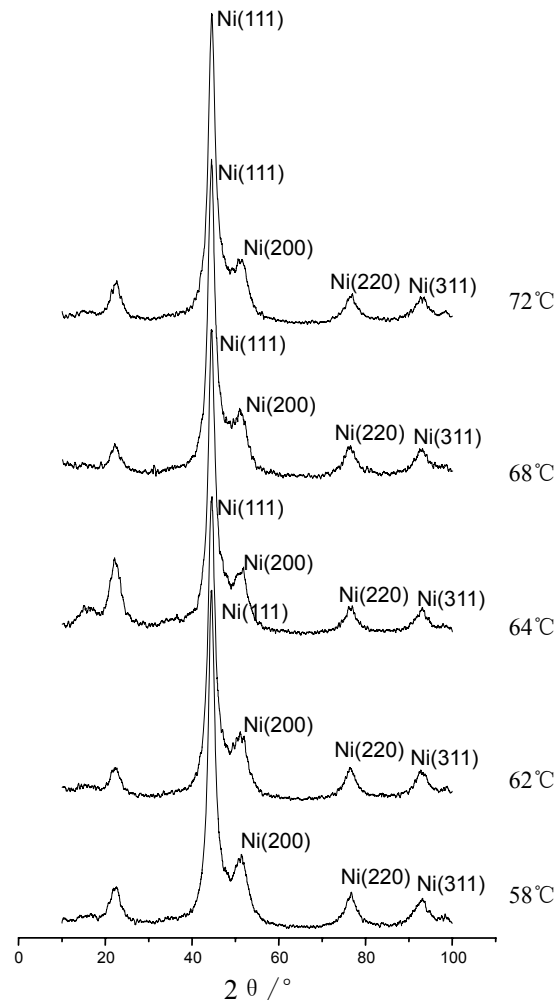


Fig. 6 XRD results of veneers plated under different temperatures

Conclusions

Wood veneer was electroless nickel plated to successfully prepare electrical and electromagnetic shielding wooden composite material under the conditions that plating solution was 500 mL, plating time was 30min and plating temperature was 62°C. The layer was microcrystalline and had metal luster for its low P content. Electromagnetic shielding effectiveness of veneer plated under above mentioned conditions was close to 55–60 dB at the frequencies from 9 kHz to 1.5 GHz. Its surface resistivity was lower than $0.4\Omega/\square$. All those can meet general electromagnetic shielding demand

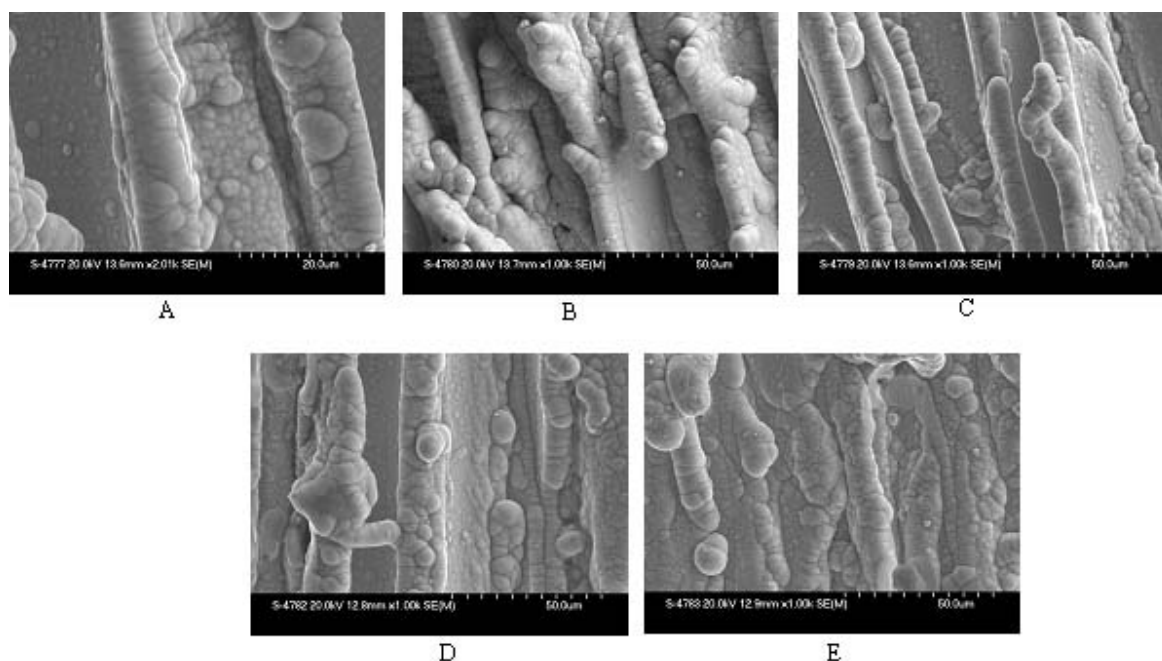


Fig.7 SEM photos of veneers plated under different temperatures

A: 58℃ B: 62℃ C: 64℃ D: 68℃ E: 72℃

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